The Arc of Progress: Getting to Zero Energy and Zero Carbon in the 21st Century

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ABSTRACT

Just two decades ago, the hyper-efficient Lewis Center for Environmental Studies opened at Ohio's Oberlin College to become the first North American Zero Energy (ZE) commercial building – offsetting 100% of its annual energy use with onsite renewable generation. Twelve years later, the first study on ZE projects listed 60 buildings, and today ZE buildings have grown tenfold approaching 700 documented projects spanning all major building types, sizes, and climate zones (NBI Getting to Zero 2020). While this dataset shows 'proof of the possible,' ZE remains greatly under-adopted in relation to technical potential and policy needs. As the urgency around the climate crisis grows, the groundwork laid by ZE buildings must be a springboard from energy to carbon reduction in the built environment. While early ZE buildings were the singular efforts of visionary design teams and owners, the shift now from kWh to tons of CO_2 is driven by rapid momentum in policy and regulatory approaches that provide the framework to affect all buildings in the next decade.

This paper presents the trajectory of ZE and Zero Carbon (ZC) through the lens of evolving policy trends and pathways used to scale ZE and ZC buildings as key components of carbon reduction strategies. Leading jurisdictions are developing roadmaps, policy tools, energy codes, and other mechanisms to create an Arc of Progress toward this trajectory. It describes the core foundations of ZC policies and includes examples to support policymakers, regulators, governments, program managers and other change makers in their climate action goals.

Building a Framework to Carbon Reduction Policies

The **Arc of Progress** toward carbon reductions in the built environment is grounded in the history and foundation laid in two key areas – energy efficiency and renewable generation. Energy efficiency programs for buildings and appliances emerged from the 1975 adoption of the Energy Conservation and Production Act (ECPA) (ASE 2013) and gained support as a means to offset energy generated from predominantly fossil fuel-burning power plants and to reduce consumer utility costs. The same year, ASHRAE published its first Standard 90.1, Energy Conservation in New Building Design, giving guidance to building designers and engineers and providing a key tool for evolving efficiency programs.

Renewable Portfolio Standards (RPS) began to establish the framework for a lower carbon grid by requiring that a specified portion of a state's electricity supply come from renewable energy generation. Iowa, in 1983, became the first state to adopt an RPS; by 2000, there were 12 more states and today 29 states, Washington DC, and three territories have RPS requirements (NCSL 2019). Globally, wind and solar are predicted to make up almost 50% of world's electricity by 2050, and the predicted total investment in renewable generation resources between 2019 and 2050 is over $10 trillion (Bloomberg NEF 2019).

After more than three decades, these two foundations are solidly in place and remain critical parts of achieving zero carbon buildings, but the spotlight must now be on a wider set of strategies to achieve meaningful carbon and other greenhouse gas (GHG) reductions. Concerns over carbon emissions are now driving building industry programs and policies to expand beyond energy efficiency to deliver carbon neutrality to mitigate climate change impacts.

Residential and commercial buildings account for 40% of total energy consumption and 39% of total annual carbon emissions in the United States (EIA 2019). Fossil fuel combustion in buildings alone is responsible for 29% of annual U.S. carbon emissions – a reduction since a peak in 2005 due to energy efficiency efforts (Leung 2018). Efficiency programs must continue to push beyond simply paying dollars for widgets to integrated, innovative design strategies and technologies. Renewable energy installation at the building site must be combined with holistic thinking and controls to optimize time of use and the exchange of energy between the building and the grid. And, additional policy foundations must be laid to make buildings part of the carbon solution.

The result of all these actions are buildings that use less energy, even zero net energy, and greatly reduce carbon and other GHG emissions. However, a ZE building is not equivalent to a ZC building, although in some regions with a particular generation resource mix, they can be. For the purposes of this paper, we use the terms zero energy and zero carbon to mean buildings that consume only as much energy as is produced onsite (or nearby) through clean, renewable resources and zero carbon to mean a zero energy building that has offset its carbon footprint.

The Five Foundations of Zero Carbon Building Policies

A comprehensive approach to achieving climate action goals in both residential and commercial buildings relies on developing policies that are soundly built on five foundations shown in Figure 1. This simple yet valuable representation of the five foundations provides a framework for policy and program leaders to form their approach to carbon reduction.

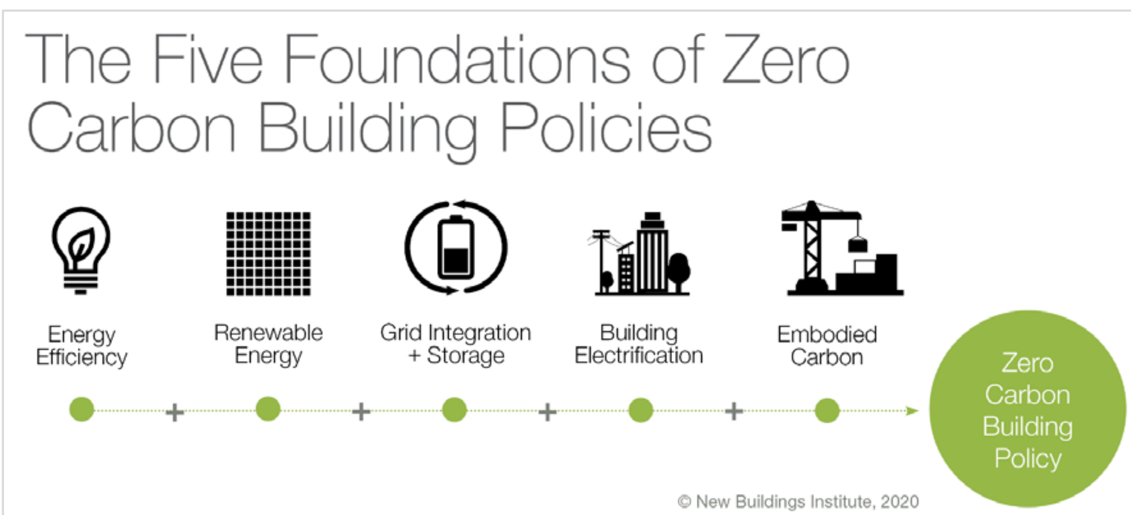

Figure 1. The five foundations of zero carbon building policies. *Source:* NBI 2020.

Great progress has been made on energy efficiency and renewable energy as described above, but truly scaling zero energy and zero carbon buildings will require bigger thinking and bolder approaches. The other three foundations expressed in Figure 1 are earlier in their development and adoption but are rapidly gaining momentum and recognition through technical development, technology capabilities, and emerging policies. All five foundations are described below.

Foundation 1: Energy Efficiency

Energy efficiency is the primary pathway for least-cost actions to achieve energy saving and resultant carbon reductions in buildings in most locations. For decades, energy efficiency has been the "first fuel" in the energy portfolio, cleanly offsetting the need for generation at lower cost than all other options. Energy efficiency today reflects a range of strategies that are co-optimized with the other Zero Carbon Foundations. Examples include high-efficiency envelope measures that provide greater periods of passive thermal comfort and daylight as a resiliency benefit, and smart controls for peak and time-of-use load shifting to help harmonize with a decarbonized grid.

Many jurisdictions and policymakers have decades of experience writing codes that lead to energy savings, including zero energy building codes and building electrification reach codes. Washington State led the way by legislating energy and carbon reduction targets. State law requires that the State Energy Code be designed to:

"Construct increasingly efficient homes and buildings that help achieve the broader goal of building zero fossil-fuel greenhouse gas emission homes and buildings by the year 2031." (RCW 19.27A.020). Additionally, the code states: *"Residential and Nonresidential construction permitted under the 2031 state energy code must achieve a 70% reduction in annual net energy consumption (compared to the 2006 state energy code)." (RCW 19.27A.160)*

Foundation 2: Renewable Energy

Promoting zero carbon and zero carbon-ready buildings requires the understanding that while we progress on the supply-side of clean energy we need to layer in distributed generation at the building or site level and establish alternative acquisition models. Since not all building types and locations will have access to enough onsite renewable energy to achieve an annual zero energy balance, some building owners are turning to purchase renewable energy from off-site locations to meet their renewable energy target or requirement. Renewable energy costs have fallen dramatically in recent years, with some power purchase agreements now coming in under $20/MWh (Weaver 2019). Policymakers must be mindful of this need and ensure appropriate and verifiable crediting of off-site renewable energy sources. Programs such as community solar, power purchase agreements, and offsite shared corporate facilities are all viable options.

A leading example is the California Department of General Services (DGS), which manages a portfolio of 69 state-owned buildings totaling 18.5 million square feet across the state. DGS entered into two 20-year community solar agreements with the Sacramento Municipal

Utility District (SMUD), the city's community-owned nonprofit electric service, to generate 39 megawatts of renewable energy at an offsite solar farm. This agreement is the largest community solar project of its kind in the nation—creating enough electricity to power about 8,200 homes per year (about 74 gigawatt hours) (CA DGS 2018).

Foundation 3: Building-Grid Integration and Storage

Transitioning to a low-or-zero carbon electricity grid means replacing fossil fuel-burning power plants with carbon-free generation such as wind and solar. Yet these key solutions are variable resources – available only when the sun is shining or the wind is blowing – and cannot be turned on or off like a fuel-powered thermal plant. As such, we need to balance energy demand with this new supply. Buildings can be key enablers of the transition to a decarbonized electricity grid, or could hamper and slow that transition. By better matching their demand with conditions on the grid such as overall system demand, carbon intensity, and cost, the built environment can transform from contributing to the problem to a critical part of the solution.

Best-practice policies around building-grid integration are still being developed. Integrated approaches consider both passive design and construction approaches that optimize building load shape to minimize grid operational carbon as well as active approaches that enhance energy flexibility behind the meter. Taking an integrated approach is critical. While battery prices have dropped fast and are predicted to fall below $100/kWh by 2023 (Bloomberg NEF 2019) this still greatly exceeds the cost of load shifting and other strategies: *using buildings as batteries* often delivers greater impact at lower costs.

The Advanced Water Heating Initiative (AWHI) is one example of collaborative progress in this arena: a consortium of West Coast utilities has come together to align program, market, technical, and policy innovations that will greatly accelerate the adoption of heat pump water heater (HPWH) products (AWHI 2020). HPWHs can help address three of the five foundations at once: they are far more efficient than legacy technologies, they can electrify a combustion appliance, and they provide opportunities for enhanced building-grid integration through smart controls, energy storage, and energy flexibility.

New metrics that guide policymaking and design teams on delivery of building-grid integration will be critical to the success of those policy approaches. This topic is discussed in detail by one of the authors of this paper and others in these two concurrently published papers:

- Carbon Goals Call for Carbon Metrics: Bringing Time of Use Energy Efficiency into Building Codes (Edelson 2020)
- New Metrics for Building-Grid Integration (Miller and Carbonnier 2020)

Foundation 4: Building Electrification

Onsite combustion of fossil fuels contributes to local pollution, greenhouse gas emissions, and indoor air quality issues. Upstream of the building, the oil and gas supply has GHG leak impacts with a 20-year global warming potential roughly comparable to the CO_2 emissions associated with all U.S. natural gas consumption (Alvarez 2018). Even onsite combustion of biomass adds near-term global warming potential and can create local pollution issues unless it is fully controlled for emissions.

A policy path to the elimination of most, if not all, onsite combustion of fossil fuels is frequently called Building Electrification. Building Electrification policies typically mandate or incent the use of electric technologies to displace traditional natural gas applications in buildings. Yet, many jurisdictional climate action plans do not embrace full or partial electrification objectives in the short term. But as renewable portfolio standards continue to take hold, and the electricity grid becomes increasingly carbon-free, the need for building electrification policies toward climate objectives will increase.

A map of over 30 adopted Building Electrification policies is shown in Figure 2 in the Key Policy Examples section below. As the electricity grid decarbonizes and the emissions impacts of electricity usage shrink, the emissions impacts of onsite combustion will remain, and the emissions benefits of Building Electrification will grow. In cases where remaining combustion is unavoidable, policies should:

1. Emphasize the use of qualifying renewable fuels with strict standards.
2. Require that onsite combustion appliances be electrification-ready: install all wiring, power supply, outlets, physical space, etc. needed for future appliance electrification.
3. Ensure that onsite combustion for buildings is not permitted to exacerbate local air pollution and indoor air quality problems.

Foundation 5: Embodied Carbon

Building materials and construction accounts for fully 11% of global energy-related carbon emissions (UNEP 2017). As buildings increasingly target high-efficiency levels and low/zero carbon operations, the embodied carbon in the materials used to construct buildings constitutes a growing share of life cycle carbon impact.

There are two general ways to measure embodied carbon: within product classes (e.g. using Environmental Product Declarations (EPDs) to compare different sources of concrete) or on a whole-building basis (e.g. using tools such as EC3, One-click LCA and Athena). While some life-cycle and carbon assessment tools have been in place for over a decade there is increasing attention on the need to engage greater resources in the review of existing, and development of new, embodied carbon assessment tools that provide program, policy and industry confidence in the results. There is an enormous range of materials in the built environment, but policies are starting with the most ubiquitous materials – concrete and steel.

Reducing embodied carbon in building projects does not necessarily cost more. Stacey Smedley, Skanska Director of Sustainability, said: "*So far, low-carbon options are price-competitive compared to higher embodied carbon options.*" (ULI 2020).

A few leading jurisdictions have implemented internal policies to minimize embodied carbon emissions from their own facilities, including the City of Portland, Oregon (Portland 2020). In November 2019, Marin County became the first jurisdiction to approve a low-carbon code, which adds a low-carbon concrete specification to the Marin County Building Code. The code includes pathways for compliance with either reduced cement levels or lower-emission supplementary cementitious materials, such as fly ash (Marin County 2019).

Codes for embodied carbon should be carefully tailored to achieve stated policy objectives. Policy provisions for embodied carbon can provide an opportunity to directly address these emission impacts. Accounting for the carbon intensity of building materials in new construction and existing building renovations will spotlight the GHG implications of development decisions, design choices, and material selection.

Key Policy Examples on the Path to Zero Carbon

Leading organizations from both private and public sectors have taken steps to achieve zero energy and zero carbon outcomes through policy. This section presents a few selected case studies that demonstrate real-world applications of leading-edge policymaking.

Getting to Zero in Existing Buildings: New York City Emissions Targets

In 2019, New York Governor Andrew Cuomo announced the Green New Deal for the state, which lays out a range of aggressive climate protection actions to put New York on a path to economy-wide carbon neutrality. While the state's objectives are being aggressively laid out by the New York State Energy Research and Development Authority (NYSERDA) through the development of a comprehensive "Carbon Neutral Buildings Road Map" to be published in 2021 (Hale 2019), New York City has taken actions critical to the state's success in this effort.

New York City enacted Local Law 97 in 2019, which is considered "the most ambitious climate legislation for buildings enacted by any city in the world" (Urban Green 2020). The new law places buildings on a path to meet the city's goal to reduce overall carbon emissions 80% by 2050. This will affect buildings greater than 25,000 square feet and nearly 60% of the city's building area. Local Law 97 sets emissions intensity limits that are evaluated based on an annual carbon emissions basis: tons of carbon per square foot and includes fines for non-compliance – the first such building carbon fines in the country. The targets vary by building use type. To achieve compliance, many buildings will have to replace heating and/or air conditioning systems with models that are more efficient, upgrade building envelopes (windows and insulation), and use electricity from clean sources like solar and hydropower.

In June 2019, the New York City Council passed technical amendments to the law, including a provision clarifying that building carbon emissions from electricity can be based on time of use. The consideration of time-varying carbon impacts is a good example of how cutting-edge research can inform policy development. Critically, Local Law 97 also includes significant equity provisions to ensure that low-income and disadvantaged communities are not left behind. This leading legislation demonstrates a clear pathway for getting existing buildings to zero energy, which is critical for achieving society-wide carbon reductions and even neutrality.

City-scale Electrification for New Buildings

Berkeley, California, was the first U.S. city to ban natural gas infrastructure in new low-rise buildings, beginning January 1, 2020 (Berkeley 2019). This ordinance leverages the city's authority under the California Constitution to prohibit installation of hazardous internal gas piping infrastructure when granting entitlements for new buildings, and as a result avoids

California Energy Commission (CEC) regulations associated with asking permission to amend an energy efficiency standard. The effect of this legislation is that builders are prohibited from applying for entitlements that include gas infrastructure – gas piping for water or space heating, cooking, laundry, etc. – except for specific building systems that have not yet been modeled for all-electric design by the CEC.

The City of San José, California, combined two pathways to drive the built environment toward low-carbon outcomes: a limited gas ban ordinance and a reach code (a city-specific mandatory building energy code that is more stringent than California's base building energy code) (San José 2020). Specifically:

1. The gas ban, passed by San José City Council in October 2019, prohibits natural gas infrastructure in new single-family, low-rise multi-family buildings, and detached accessory dwelling units.
2. San José's reach code overlays the base code and includes additional requirements related to energy efficiency, water efficiency, electrification, electric vehicle (EV) charging infrastructure, and onsite renewables.

Electrification readiness requirements are an important piece of this approach. For example, in a nonresidential application, a designer may choose to specify a gas water heater but must also include a 240V 30A circuit, a condensate drain, and 700 CFM of make-up air. This eliminates barriers to switching from a gas water heater to a heat pump water heater in the future. Similar requirements exist for clothes drying, cooking, and other gas-burning equipment.

Reach code requirements vary by building type as shown in Table 1. The gas ban ordinance does not apply to new high-rise multifamily or nonresidential buildings, but the reach code's increased compliance margins and electrification readiness requirements are intended to push designers toward electrification of building systems.

This trailblazing approach will cut GHG emissions from San José's new buildings by 90% (Stamas and Delforge 2019). Cities around the country are watching and learning from the leadership of Berkeley and San José, California.

Table 1. San José reach code requirements by building type and fuel source

Building type	**All-electric**	**Mixed-fuel**
Single Family	Meet Base Code	Not Permitted
Low-Rise Multifamily	Meet Base Code	Not Permitted
High-Rise Multifamily, Hotel, Motel	Meet Base Code	6% better than base code, Electrification Ready, Solar Ready
Office, Retail	Meet Base Code	14% better than base code, Electrification Ready, Solar Ready
Industrial, Manufacturing	Meet Base Code	Electrification Ready, Solar Ready

Building Electrification policies, as one of the critical five foundations to Zero Carbon Policies, are growing in California and starting to be considered elsewhere. Figure 2 provides a snapshot of 30 jurisdictions with adopted electrification policies from NBI's tracking. This is built and cross-checked in conjunction with similar tracking from the Building Decarbonization Coalition and the Sierra Club and is a highly valuable reference for cities looking to move in this direction and show constituents and councilors evidence of this trend.

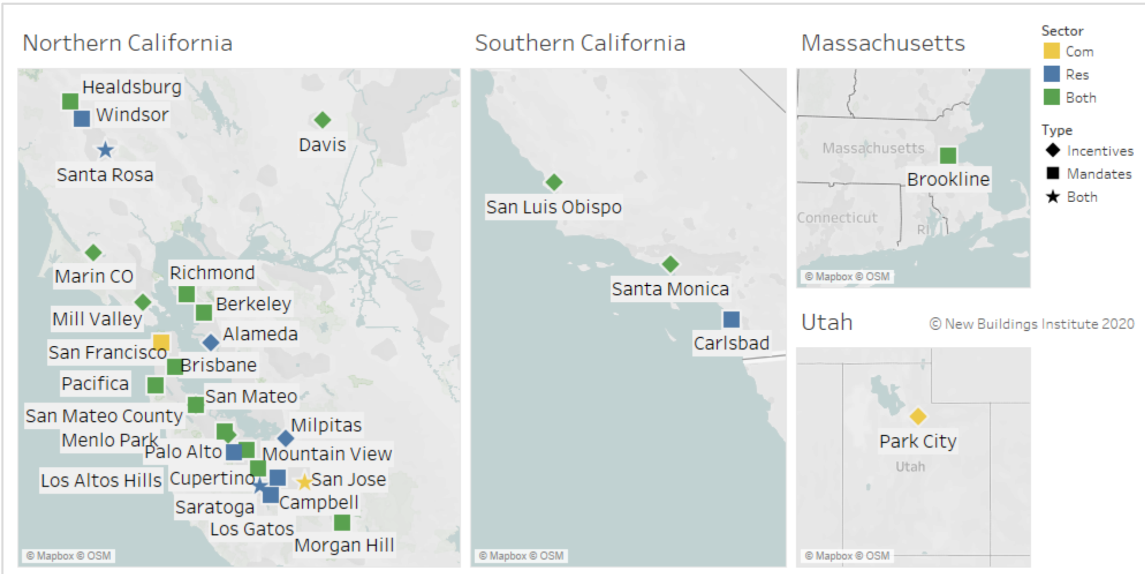

Figure 2. Jurisdictions with building codes that require or incent all-electric buildings. *Source:* NBI 2020.

Vancouver and the British Columbia Step Code

Local governments in British Columbia, Canada (BC), can choose to go beyond the requirements of the base building code by adopting the BC Energy Step Code: a provincial regulation to incentivize or require a level of energy efficiency in new construction. The BC Energy Step Code defines a set of building energy efficiency targets and groups them into *steps:* increasing efficiency outcomes along the path to 80% carbon reduction by 2050. These steps can be adopted gradually by local governments. This provides a prescriptive pathway to achieve energy efficiency and emissions reductions across diverse communities, jurisdictions, and building types. The BC Energy Step Code utilizes a series of metrics such as:

- Thermal Energy Demand Intensity (TEDI): annual modeled heating energy needed to maintain a stable interior temperature, taking into account heat loss through the envelope and passive gains, expressed in kWh/(m^2 year)
- Mechanical Energy Use Intensity (MEUI): annual modeled energy used by space heating and cooling, ventilation, and domestic hot water systems, expressed in kWh/(m^2 year)
- Total Energy Use Intensity (TEUI): the modeled amount of total annual energy used by a building, per unit of area, expressed in kWh/(m^2 year)

These targets provide pathways for policymakers to push designers to optimize specific building systems and components: TEDI targets influence a building's form factor, MEUI targets drive enhanced mechanical system energy performance, etc. Additional metrics such as air exchanges per hour or air leakage rate enable a focus on other aspects.

The City of Vancouver has utilized the steps set forth in the BC Energy Step Code to create its own building efficiency standards. Utilizing the BC Energy Step Code, Vancouver established limits using TEDI and TEUI, offered a Passive House alternative compliance path, required airtightness testing, and more. The BC Energy Step Code significantly enhances energy code consistency and predictability across local governments and provides clear timelines for future updates that will help businesses to invest in and develop products and skills to meet the next steps in requirements.

Microsoft's Corporate Carbon Targets: Internal Carbon Tax and Negative Emissions

Carbon reduction policies are not exclusive to governments. Microsoft is just one example of a large global corporation setting an aggressive emissions target: achieving carbon negative operations by 2030. While it is increasingly common for businesses to set targets for their operational carbon emissions, Microsoft's targets are unusual in that they expand the scope to include supply chain carbon emissions, their largest emissions source as shown in Figure 3, and focus on both efficiency and carbon removal strategies. Microsoft's commitment states:

"By 2030 Microsoft will be carbon negative, and by 2050 Microsoft will remove from the environment all the carbon the company has emitted either directly or by electrical consumption since it was founded in 1975." (Microsoft 2020)

Achieving these goals will require actions related not only to future efficiency and emissions reductions, but also aggressive offsets for carbon already released into the atmosphere. Microsoft's actions include shifting to 100% renewable energy and 100% electric operations for all data centers, buildings, and campuses. In fact, the company paid $23.6 million to bypass Puget Sound Energy (PSE) in 2017 because the utility was unwilling or unable to decarbonize its energy supply enough to satisfy Microsoft. PSE lost its biggest customer and Microsoft gained the ability to procure carbon-free power directly on wholesale markets (Bernton 2017).

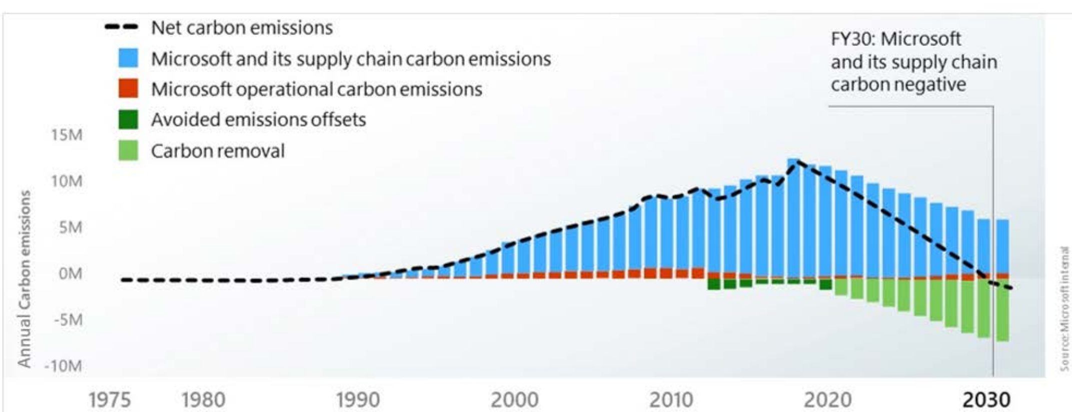

Figure 3. Microsoft's pathway to carbon negative by 2030. *Source:* Microsoft 2020.

In July 2020 Microsoft will begin phasing in an internal carbon tax. This tax will start at $15/metric ton of CO_2 and will cover all direct emissions (e.g. fleet vehicle exhaust), upstream emissions from energy (e.g. electric power plant emissions), and indirect emissions from travel. All other indirect emissions (e.g. supply chain emissions) will start at a lower price per ton, with increases phased in over time. The company plans to develop a portfolio of negative carbon emission technologies including afforestation, reforestation, soil carbon sequestration, bioenergy coupled with carbon capture and storage, and direct air capture. Microsoft states that:

"… our internal carbon tax isn't a "shadow fee" that is calculated but not charged. Our fee is paid by each division in our business based on its carbon emissions, and the funds are used to pay for sustainability improvements." (Microsoft 2020).

The Path Ahead: Key Takeaways and Recommendations

The Arc of Progress is currently on an uphill climb. There are a multitude of challenges and complexities to make Zero Carbon Policies the new order, but examples and foundations are growing and transferable. Today's long-standing, well-accepted energy efficiency and renewable energy policies and programs provide a solid platform for tomorrow's policies and programs.

Building the arc across these five foundations to a full set of plans for adopting, implementing, and enforcing zero carbon policies will require even greater industry engagement as we collaborate on the factors impacting actual zero carbon outcomes. In parallel with expanding on the strong policy leadership reflected in this paper, we must make progress on the technical areas in conjunction with for-profit partners that will gain increased market share for emerging technologies. Examples include:

- advancing space and water heat pumps to electrify buildings – particularly those with retrofit potential and with low-to-zero greenhouse gas warming potential,
- making the case for electric cooking,
- smart control technologies for optimizing building-grid interfaces,
- thermal and battery storage strategies
- metering for performance verification, and
- accurate measurement and price signals for embodied carbon in materials.

The building industry has shown incredible aptitude to deliver buildings that meet these objectives (Getting to Zero 2018). In the face of the call for climate action, building policies can drive and support a key portion of that action. We are all framing the future.

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